

EFFECTS OF INCOME ON DRUG CHOICE IN HUMANS

R. J. DEGRANDPRE, WARREN K. BICKEL, S. ABU TURAB RIZVI,
AND JOHN R. HUGHES

UNIVERSITY OF VERMONT

The effects of income (money available to spend during the experimental session) on human choice were examined in a concurrent-schedule arrangement. Subjects were 7 nicotine-dependent smokers, and reinforcers were puffs on the subject's usual brand of cigarette ("own") and puffs on a less preferred brand of cigarette with equal nicotine content ("other"). Across sessions, income varied and the price of the two reinforcers was held constant, with the other puffs one fifth the price of the own puffs. As income increased, consumption of own puffs increased while consumption of the less expensive other puffs decreased. These effects of income on choice were highly consistent across subjects. For some subjects, however, income had little effect on total puff consumption. Finally, an additional condition examined whether price and income manipulations would have functionally equivalent effects on choice by repeating an income condition in which the price of the other brand was increased. Although the increased price of the other puffs decreased their consumption in 4 subjects, 2 subjects showed increased consumption of the other puffs at the higher price. The results, when defined in economic terms, indicate that the own puffs were a *normal* good (consumption and income are directly related), the other puffs were an *inferior* good (consumption and income are inversely related), and the direct relationship between consumption of the other puffs and their price is defined as a *Giffen-good* effect. The latter result also suggests that for these 2 subjects, price and income manipulations had equivalent effects on choice. These results extend findings from previous studies that have examined the effects of income on choice responding to human subjects and drug reinforcers, and provide a framework for further experimental tests of the effects of income on human choice behavior. Methodological and theoretical implications for the study of choice and for behavioral pharmacology are discussed.

Key words: behavioral economics, behavioral pharmacology, choice, demand, drug reinforcers, nicotine, drug policy, income, lever press, humans

Numerous studies have investigated choice between drug reinforcers and between drug and nondrug reinforcers. Under these procedures, two or more reinforcers are available in a concurrent-schedule arrangement. Responding on one manipulandum is maintained by drug reinforcement, while responding on another manipulandum is maintained by either a different dose of the same drug, a different drug, or a nondrug reinforcer. These studies are typically used to assess the reinforcing effectiveness of one stimulus relative to some

other stimulus. As stated by Katz (1990), the relative frequency of responding for one reinforcer "is used as an indication of the differences in reinforcing effectiveness of the two consequences" (p. 285).

For example, one study examined choice responding for different doses of intravenous cocaine in rhesus monkeys using concurrent variable-interval 1-min schedules (Iglauer & Woods, 1974). Greater responding (and sometimes exclusive responding) occurred for the higher dose, suggesting greater effectiveness of the higher doses. Other studies have examined choice between different drug reinforcers. For example, one study examined the effects of methylphenidate dose on responding maintained by it and one of two doses of cocaine (Johanson & Schuster, 1975). Preference for cocaine decreased as the comparison dose of methylphenidate increased, suggesting, again, that the effectiveness of a reinforcer may vary as a function of dose. These and numerous other studies have shown the utility of choice procedures for examining relative reinforcing

This research was conducted when the first author was a predoctoral student in the Department of Psychology, University of Vermont. This work is funded by a Sigma Xi Grant-in-aid (R.J.D.), National Institute on Drug Abuse Training Grant T32 DA-07242 (R.J.D.), and Grants RO1 DA-06626 (W.K.B.), and PHS KO2-00109 (J.R.H.). We thank Melissa Jurgens and Michael Layng for their assistance in preparing the manuscript. Send requests for reprints to the first or second author at the Department of Psychiatry, Human Behavioral Pharmacology Laboratory, 38 Fletcher Place, University of Vermont, Burlington, Vermont 05401-1419.

effectiveness of pharmacological and non-pharmacological substances (for a review of studies on choice and reinforcer effectiveness, see Katz, 1990).

Other studies suggest that choice may also be a function of variables that are independent of the reinforcers (e.g., intertrial interval; ITI). One such study examined whether choice between heroin and food, at constant magnitudes, would vary as a function of ITI (Elsmore, Fletcher, Conrad, & Sodetz, 1980). Even though an equal number of choices for heroin and food occurred at low ITIs, heroin choices decreased considerably more than food choices as ITI increased. This finding is important in showing that choice between two reinforcers can be altered by variables that are independent of the schedule and magnitude of reinforcement for the concurrently available reinforcers. More recently, the manipulation made in the Elsmore et al. study (1980) has been conceptualized in terms of the economic notion of *income* and has been further shown to affect choice between concurrently available different reinforcers (Silberberg, Warren-Boulton, & Asano, 1987).

Income can be defined as the amount of funds, goods, or services available to any one individual at any given time (Pearce, 1986). In behavioral terms, income manipulations can be conceptualized as constraints on total reinforcement within a session. Microeconomic theory considers the relation between income and consumption and recognizes that increases in income can either increase or decrease choice of any particular good, depending on the type of good and the availability of other goods (Deaton & Muellbauer, 1980; Lea, Tarpy, & Webley, 1987). For example, an increase in income might increase seafood consumption while decreasing consumption of hamburger. The former relationship is defined in economic terms as a *normal* good (i.e., normal-good effect), and the latter is defined as an *inferior* good (i.e., inferior-good effect). Normal goods often correspond to the everyday notion of luxuries, whereas inferior goods are often necessities. In recent experimental analyses, the economic notion of income has been extended to nonhuman choice between nonidentical reinforcers (Hastjarjo & Silberberg, 1992; Hastjarjo, Silberberg, & Hursh, 1990; Silberberg et al., 1987). Consistent with the definitions

above, studies investigating income have defined income as the resources available to the organism to obtain food during the experimental session (i.e., number of trials or reinforcers per session; Battalio, Kagel, & Kogut, 1991; Hastjarjo & Silberberg, 1992; Hastjarjo et al., 1990). For example, in one study of macaque monkeys, ITI was varied as the income manipulation (i.e., number of reinforced trials per session) while session length was held constant (Silberberg et al., 1987, Experiment 1). Choice of a large bitter-tasting food pellet increased relative to a small normal pellet when income was decreased. In economic terms, the bitter pellet was an inferior good and the small normal pellet was a normal good in this context (Silberberg et al., 1987). A second study manipulating income (Hastjarjo et al., 1990) replicated the effects of income reported in the Silberberg et al. study using rats as subjects, and a third study (Hastjarjo & Silberberg, 1992) extended these findings to show that income could significantly alter choice between an immediate and delayed reinforcer in rats. The present study assessed the effect of income on drug choice in human cigarette smoking. This study also examined, in a more limited scope, whether these income manipulations might have effects on drug choice that are functionally equivalent to those of price manipulations.

Although considerable research has been conducted on choice using drug reinforcers, to our knowledge there are no laboratory studies that explicitly manipulated income using drugs as reinforcers. Nor, to our knowledge, have the effects of income been investigated in humans in a laboratory setting.

METHOD

Subjects, Apparatus, and Reinforcers

One female and 6 male smokers participated. Subjects ranged from 20 to 38 years old and smoked one or more packs of 0.6- to 1.2-mg nicotine cigarettes per day. Nicotine self-administration via cigarette smoking was used in this study because it is well established as a potent reinforcer in humans (Henningfield & Goldberg, 1983) and because it has many features of other drugs of dependence (West & Grunberg, 1991) that are responsive to en-

Table 1
Subject characteristics.

Subject	Age	Gender	Fagerstrom scores	Cigarettes per day (avg.)	Preferred brand	Nicotine/tar (mg/cigarette)
BT	35	M	8	25	American Lights®	1.2/16
JH	38	M	9	30	Winston®	1.1/17
JR	22	M	8	30	Marlboro®	1.2/17
KC	20	F	7	20	Camel Lights®	0.7/09
KS	36	M	9	30	Merit®	0.6/08
PZ	25	M	7	25	Camel® filter	1.0/15
WR	20	M	8	20	Marlboro®	1.2/17

vironmental variations (Hughes, 1989). Subjects were recruited from newspaper advertisements, were in good health, and reported no medication usage or drug or alcohol abuse other than nicotine. Subjects had to score a minimum of 7 on the Fagerstrom's Tolerance Questionnaire (Fagerstrom & Schneider, 1989) to participate in the study. Subjects were compensated for their participation with monetary payment that was not contingent upon any particular type of performance in the experimental session. Table 1 lists these and other relevant characteristics of the subjects.

An Apple IIe® microcomputer controlled and obtained data from a response console (61 cm by 30 cm by 46.5 cm) that contained three Lindsley plungers (Gerbrands No. G6310; centered from left to right on the face of the response console). Subjects responded on the left and right plungers only. Responses made on the center manipulandum produced no programmed effect. Sessions were conducted in rooms that contained one response console, overhead fluorescent lighting, a desk lamp, several current magazines, the daily local newspaper, and a radio. Carbon monoxide from expired air samples from the lungs was measured using a MiniCO® Carbon Monoxide Breathkit (produced by Catalyst Research Corporation).

Throughout the experiment, each subject had access to two brands of cigarettes. The first brand was the subject's own brand. The second brand was determined either prior to or following the first session. The subject was provided with three brands; each was different than his or her own brand but had an equivalent nicotine rating (based on Federal Trade Commission [FTC] ratings, 1991). The sub-

ject was asked to rate the three brands from most to least preferred. Following this assessment, the least preferred brand was provided to the subject as the second brand (referred to as "other" brand below). Those subjects who completed this assessment after the first session were provided with one of these three brands (chosen arbitrarily) during the first session.

Procedure

Subjects participated in a minimum of 11 3-hr sessions (range, 11 to 18), one session per day. The number of sessions varied due to subject dropouts (Subject PZ) and differences between subjects in the time necessary to reach stability. Sessions were conducted 3 days per week (either Tuesday, Thursday, and Friday or Monday, Wednesday, and Friday). Prior to each experimental session, the subject was required to abstain from smoking to reach a carbon monoxide (CO) level of 50% or lower than his or her nonabstinence level (obtained during the initial interview). This technique was used because expired air CO has been shown to correlate with the number of cigarettes smoked (Henningfield, Stitzer, & Griffiths, 1980). Subjects were instructed to abstain from cigarette smoking for 5 to 6 hr in order to meet this criterion. If a subject failed to reduce his or her CO to the required level, the session was canceled without payment and was rescheduled.

Next, each subject took one uniform puff on his or her own cigarette 30 min prior to the start of the session (cigarettes were provided by the experimenter). This 30-min presession puff was used to equate the time from last cigarette exposure across subjects (see Henningfield & Griffiths, 1981).

Instructions. On the 1st day of the experiment (Session 1), subjects were instructed:

In this study you can respond on the left and right levers to earn puffs. You will have a certain amount of money provided to you to spend on puffs during the session. On different days the amount of money may vary and so will the cost of the puffs for both types of puffs. Prior to beginning each day you will be provided with this sheet, which will inform you about the parameters above. When you have earned puffs, the cost of these puffs will be subtracted from the amount you have remaining, which will be shown on the screen. Also, when you have earned puffs you will have 5 minutes to take them. You will be instructed to inhale, hold for 5 seconds, and exhale. The screen will count down the 300 seconds and will tell you when you can respond again by displaying "You may respond now."

Also prior to the first session and all other sessions, subjects were given the following daily parameters for that session:

1. Your brand (left lever/one response required)
Puffs cost: _____ cents for two puffs.
2. Other brand (right lever/one response required)
Puffs cost: _____ cents for two puffs.
3. Today you have \$ _____ to spend on puffs.

Daily procedure. The sequence of conditions varied across subjects because the procedure was modified after the first 3 subjects (JH, KS, and WR) completed the study. The income conditions in the modified procedure were more systematic than in the earlier procedures and thus will be described first.

All subjects who completed the modified procedure completed a minimum of four income conditions: baseline income (Condition A), one half baseline income (Condition B), one third baseline income (Condition C), and one sixth baseline income (Condition D). These percentages of income were rounded up to the nearest \$0.50. For each of these income conditions, price of the subject's own and other puffs was \$0.50 and \$0.10, respectively, for two puffs. Income for the initial baseline session was set at \$15.00. Income for all remaining baseline sessions (i.e., baseline income) was that amount of money spent in the first session rounded up to the nearest \$0.50. The experimental design for these income-manipulation conditions can be described as an ABACAD

design. That is, after establishing a baseline, the three income conditions were examined with baseline conditions interposed between them. Each baseline condition was maintained until choice of the own puffs was stable (i.e., plus or minus one self-administration of own puffs over three sessions; JH's data did not meet this stability criterion). The sequence of the three income conditions varied across subjects in a mixed order (see Table 2). Each condition was completed in a single session (except for baseline sessions).

Following the completion of these income conditions, some subjects completed additional conditions. First, additional income conditions were used to assess the effects of a more complete range of income amounts on drug choice (see Table 2). Second, a single session was conducted in which the price of the other puffs was raised from \$0.10 to \$0.25 (for two puffs) at one of the income amounts previously tested (i.e., Conditions B, C, or D). The price of the other puffs was increased to examine whether the price manipulation would produce an increase or decrease in consumption of that good relative to choice at the lower price at the same income amount.

The procedure for the 3 subjects who participated first was identical to the above procedure except that (a) baseline income was an amount that constrained subjects' choice responses for their own puffs such that income manipulations consisted of increases in income (instead of manipulations that decreased income), (b) subjects obtained one puff per self-administration (instead of two puffs), (c) the income conditions were selected in a less systematic fashion (i.e., not necessarily one half, one third, and one sixth of baseline income), and (d) fewer income manipulations were made (see Table 2).

Puffing procedure. After responding for puffs, the subject lit one of the cigarettes he or she was provided, but did not inhale. The subject was required to take one puff (first 3 subjects) or two puffs within 5 min according to a uniform-puff procedure in which the subject took one uniform puff, inhaled, retained the smoke in the lungs for 5 s, and then exhaled (Griffiths, Henningfield, & Bigelow, 1982). When a second puff was allowed, it was taken 25 s after the subject exhaled the first puff. Also, the experimenter observed and recorded the subject's puff topography (e.g., shallow, normal,

Table 2
Conditions and summary results in successive sessions.

Subject	Income in \$	Price in \$ (own/other)	Own puffs/ session	Other puffs/ session	\$ not spent	Distribution of responses within session ^a
BT	15.00	0.50/0.10	22	4	9.30	— ^b
	6.00	0.50/0.10	20	16	0.20	—
	6.00	0.50/0.10	20	16	0.20	1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 3L, 1R
	3.00	0.50/0.10	6	30	0.00	—
	6.00	0.50/0.10	20	18	0.10	1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 2L, 1R
	2.00	0.50/0.10	0	36	0.20	18R
	6.00	0.50/0.10	20	16	0.20	1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 2L
	1.00	0.50/0.10	0	20	0.00	10R
	6.00	0.50/0.10	20	18	0.10	1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 2L, 1R
	6.00	0.50/0.25	12	24	0.00	1R, 1L, 2R, 1L, 2R, 1L, 1R, 1L, 6R, 2L
	6.00	0.50/0.10	20	16	0.20	1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 2R, 3L
	18.00	0.50/0.10	36	0	9.00	18L
	6.00	0.50/0.10	20	20	0.00	1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 2R, 1L
	36.00	0.50/0.10	58	0	21.50	29L
	6.00	0.50/0.10	20	16	0.20	1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 1L, 1R, 3L, 1R
JH	15.00	0.50/0.10	46	8	3.10	—
	12.00	0.50/0.10	44	0	1.00	22L
	12.00	0.50/0.10	48	0	0.00	24L
	4.00	0.50/0.10	12	20	0.00	—
	12.00	0.50/0.10	40	0	2.00	20L
	12.00	0.50/0.10	32	0	4.00	16L
	12.00	0.50/0.10	30	0	4.50	15L
	12.00	0.50/0.10	44	0	1.00	22L
	12.00	0.50/0.10	40	0	2.00	20L
	2.00	0.50/0.10	4	20	0.00	5R, 2L, 5R
	12.00	0.50/0.10	26	0	3.00	18L
	6.00	0.50/0.10	24	0	0.00	12L
	12.00	0.50/0.10	22	0	6.50	11L
	12.00	0.50/0.10	24	0	6.00	12L
	12.00	0.50/0.10	30	0	4.50	15L
	4.00	0.50/0.25	12	8	0.00	—
	12.00	0.50/0.10	32	0	4.00	16L
	1.00	0.50/0.10	0	20	0.00	10R
JR ^c	3.00	0.50/0.10	5	3	0.20	1L, 2R, 3L, 1R, 1L
	2.00	0.50/0.10	1	6	0.90	3R, 1L, 3R
	2.00	0.50/0.10	1	12	0.30	9R, 1L, 3R
	2.50	0.50/0.10	3	9	0.10	3R, 1L, 1R, 1L, 2R, 1L, 3R
	2.50	0.50/0.10	3	7	0.30	4R, 2L, 2R, 1L, 1R

Table 2 (Continued)

Subject	Income in \$	Price in \$ (own/other)	Own puffs/ session	Other puffs/ session	\$ not spent	Distribution of responses within session ^a
KC	2.50	0.50/0.10	2	15	0.00	11R, 1L, 1R, 1L, 3R
	2.50	0.50/0.10	2	15	0.00	6R, 1L, 6R, 1L, 3R
	2.50	0.50/0.10	1	10	1.00	9R, 1L, 1R
	2.50	0.50/0.10	2	13	0.20	10R, 1L, 2R, 1L, 1R
	2.50	0.50/0.10	2	11	0.40	10R, 1L, 1R, 1L
	4.00	0.50/0.10	6	7	0.30	2R, 1L, 3R, 5L, 2R
	2.50	0.50/0.10	2	15	0.00	8R, 1L, 6R, 1L, 1R
	2.50	0.50/0.10	3	10	0.00	7R, 1L, 3R, 2L
	2.50	0.50/0.10	3	10	0.00	8R, 1L, 1R, 1L, 1R, 1L
	2.50	0.50/0.10	3	10	0.00	9R, 3L, 1R
	5.00	0.50/0.10	8	10	0.00	2L, 1R, 1L, 4R, 1L, 4R, 2L, 1R, 2L
	2.50	0.50/0.10	2	15	0.00	9R, 1L, 5R, 1L, 1R
	2.50	0.50/0.10	2	15	0.00	9R, 1L, 2R, 1L, 4R
	2.50	0.50/0.10	2	15	0.00	11R, 2L, 4R
	7.00	0.50/0.10	13	5	0.00	2R, 1L, 3R, 12L
	15.00	0.50/0.10	22	2	9.40	—
	5.50	0.50/0.10	18	6	0.70	—
	5.50	0.50/0.10	20	10	0.00	—
	5.50	0.50/0.10	20	10	0.00	—
	1.00	0.50/0.10	0	18	0.10	9R
	5.50	0.50/0.10	18	20	0.00	1L, 10R, 8L
	2.00	0.50/0.10	4	18	0.10	6R, 1L, 3R, 1L
	5.50	0.50/0.10	20	6	0.20	—
	3.00	0.50/0.10	8	18	0.10	1L, 3R, 1L, 3R, 1L, 2R, 1L, 1R
	5.50	0.50/0.10	20	10	0.00	3L, 2R, 1L, 1R, 1L, 1R, 1L, 1R, 4L
	4.00	0.50/0.25	12	8	0.00	1L, 4R, 5L
	5.50	0.50/0.10	20	0	0.50	10L
	4.00	0.50/0.10	14	10	0.00	5R, 7L
	5.50	0.50/0.10	22	0	0.00	11L
	16.50	0.50/0.10	28	0	9.50	14L
	5.50	0.50/0.10	22	0	0.00	11L
	0.50	0.50/0.10	0	10	0.00	5R
	5.50	0.50/0.10	22	0	0.00	11L
KS ^c	2.50	0.50/0.10	3	8	0.20	6R, 2L, 1R, 1L, 1R
	2.50	0.50/0.10	3	10	0.00	4R, 1L, 6R, 2L
	2.50	0.50/0.10	3	8	0.20	5R, 1L, 1R, 1L, 2R, 1L
	5.00	0.50/0.10	7	5	1.00	2L, 3R, 3L, 1R, 1L, 1R, 1L
	2.50	0.50/0.10	3	8	0.20	1L, 5R, 1L, 3R, 1L
	2.50	0.50/0.10	3	8	0.20	5R, 1L, 1R, 2L, 2R
	2.50	0.50/0.10	3	8	0.20	—
	2.50	0.50/0.10	3	8	0.20	—

Table 2 (Continued)

Subject	Income in \$	Price in \$ (own/other)	Own puffs/ session	Other puffs/ session	\$ not spent	Distribution of responses within session ^a
PZ	4.00	0.50/0.10	6	7	0.30	1L, 5R, 1L, 1R, 4L, 1R
	2.50	0.50/0.10	3	8	0.20	1L, 6R, 1L, 1R, 1L, 1R
	2.50	0.50/0.10	3	8	0.20	1L, 5R, 1L, 2R, 1L, 1R
	2.50	0.50/0.20	1	9	0.20	9R, 1L
	2.50	0.50/0.10	3	7	0.30	1L, 5R, 1L, 2R, 1L
	15.00	0.50/0.10	22	4	9.30	—
	6.00	0.50/0.10	22	6	0.20	—
	6.00	0.50/0.10	20	8	0.60	—
	6.00	0.50/0.10	22	2	0.40	—
	1.00	0.50/0.10	2	10	0.00	—
	6.00	0.50/0.10	22	0	0.50	11L
	3.00	0.50/0.10	10	10	0.00	4L, 2R, 1L, 3R
WR ^c	6.00	0.50/0.10	24	0	0.00	12L
	2.00	0.50/0.10	6	10	0.00	1L, 3R, 2L, 2R
	6.00	0.50/0.10	24	0	0.00	12L
	2.00	0.50/0.25	6	4	0.00	2L, 2R, 1L
	4.00	1.00/0.10	3	9	0.10	1L, 2R, 1L, 4R, 1L, 3R
	4.00	0.50/0.10	6	9	0.10	2L, 4R, 1L, 1R, 2L, 2R, 1L, 2R
	4.00	0.50/0.10	6	10	0.00	4L, 4R, 1L, 5R, 1L, 1R
	6.00	0.50/0.10	11	4	0.10	11L, 4R
	4.00	0.50/0.10	6	10	0.00	5L, 8R, 1L, 2R
	8.00	0.50/0.10	15	0	0.50	15L
	4.00	0.50/0.10	5	15	0.00	4L, 7R, 1L, 8R
	4.00	0.50/0.10	5	15	0.00	5L, 15R
	4.00	0.50/0.10	5	14	0.10	5L, 14R
	8.00	0.50/0.10	15	5	0.00	14L, 4R, 1L, 1R
	4.00	0.50/0.10	6	10	0.00	5L, 9R, 1L, 1R
	4.00	0.50/0.10	6	10	0.00	5L, 10R, 1L
	4.00	0.50/0.10	6	10	0.00	5L, 10R, 1L
	4.00	0.50/0.25	3	10	0.00	3L, 10R
	4.00	0.50/0.25	3	10	0.00	3L, 10R

^a Each response was one or two puffs (see text). L = own, R = other.
^b Dashes indicate that data were not recoverable.
^c These subjects completed original procedure (see text for details).

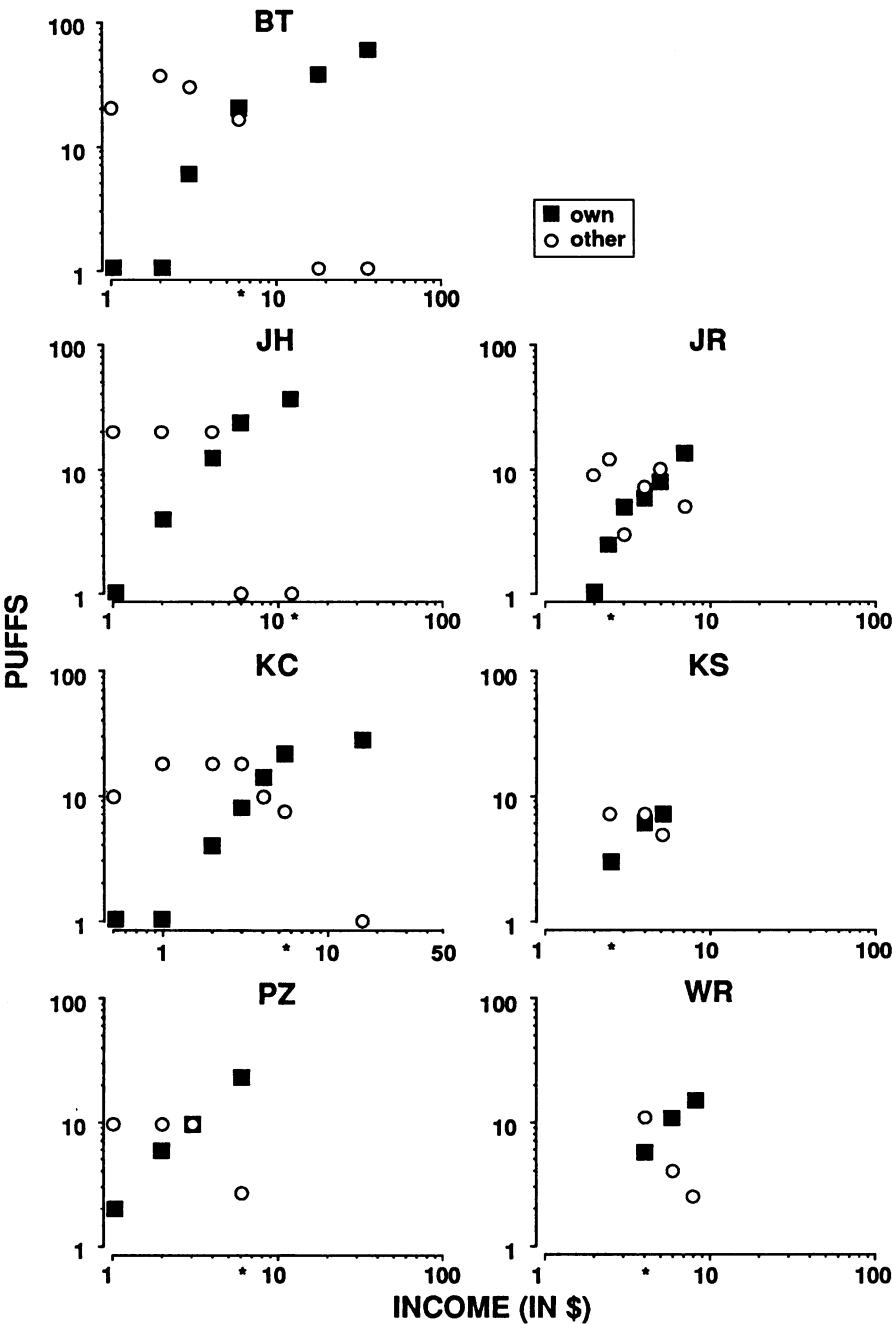


Fig. 1. Consumption (puffs) of own and other puffs is plotted as a function of income amount for all 7 subjects. Data at the baseline income amount (shown in Table 2) for each subject represent mean consumption across all baseline sessions. An asterisk is shown on the x axis to represent the baseline income.

or deep puffs) during the first session and instructed the subject not to change that topography. Topography was monitored throughout the study, and the subject was told of deviations.

RESULTS

Effects of Income

When choice of the two reinforcers (own puffs and other puffs) is plotted as a function of income amount (see Figure 1), the magnitude of the income effect is an orderly function of this variable (data are plotted in log-log coordinates to show proportional change such that the slope of the line, in economic terms, equals its elasticity coefficient; see Samuelson & Nordhaus, 1985). In all but two cases, every successive increase in income, from the lowest income amount to the highest income amount, increased choice responses for the own puffs. In those cases in which an increase did not occur (low-income conditions for BT and KC), no responses were made for the own puffs across the two consecutive income amounts (i.e., floor effect). A similar function exists in the opposite direction for the other puffs, albeit more variable (i.e., increases in income decreased choice responses for the other puffs). Several subjects' data for both own puffs and other puffs suggest an asymptote in consumption at high and low income amounts, respectively (e.g., BT and KC). To illustrate the across-subject similarity of this function for the own-puff data, these data for all 7 subjects shown in Figure 1 are collapsed into a single function in Figure 2. The effects of income on consumption of subjects' own puffs are markedly similar across subjects.

In order to illustrate better the control exerted by the income manipulation over choice responding across sessions for each subject, the data plotted in Figure 1 are plotted again in Figures 3 and 4 as a function of session order. Total puffs (own puffs + other puffs) are also plotted for each subject. Recall that Subjects JR, KS, and WR participated in the original procedure.

Changes in income across sessions significantly altered choice responding. Again, decreases in income from the baseline amount decreased choice responses for their own puffs

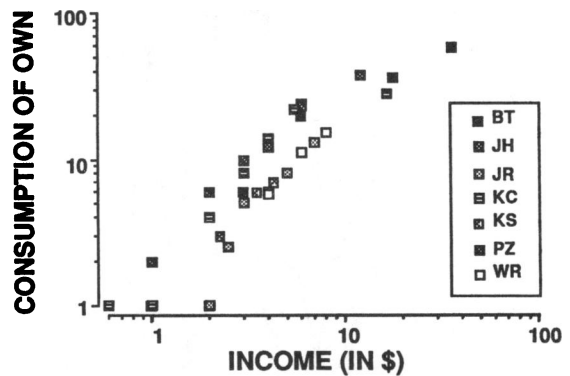
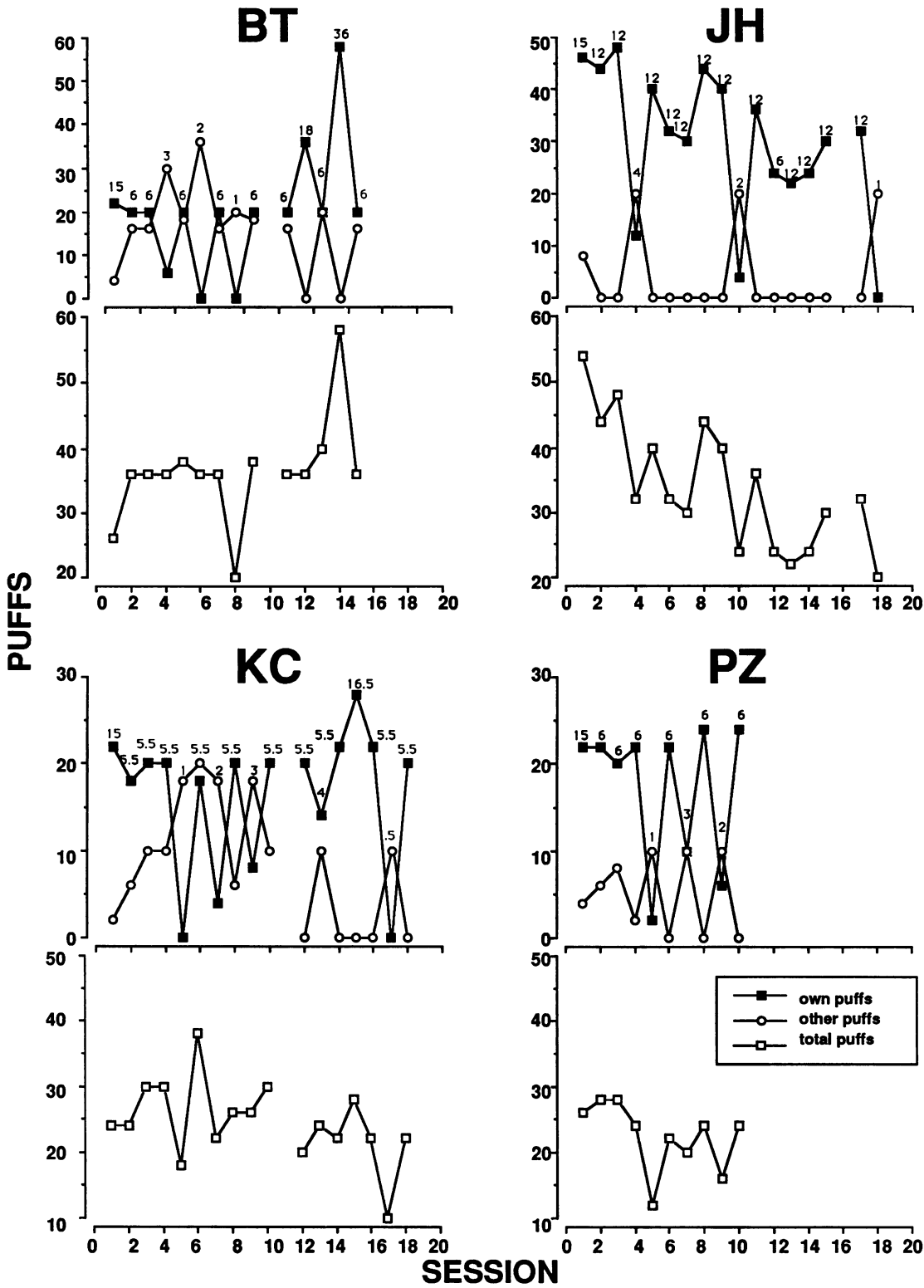


Fig. 2. Consumption (puffs) of own puffs for all 7 subjects is plotted together as a function of income amount. These data are also shown in Figure 1 separately for each subject. Data at the baseline income amount (shown in Table 2) for each subject represent mean consumption across all baseline sessions.

and increased choice responses for the other puffs. In many cases, when the session income was radically different from the previous session's or the following session's income, the reinforcer chosen reversed, such that the reinforcer preferred in one session was opposite to that of the next session.

The effects of income on total consumption were varied. First, the income manipulations had little effect on 2 subjects' (BT and WR) total consumption, even though choice was significantly affected. Note that Subject BT's total consumption was affected at very low and very high incomes. Also, Subject WR's baseline levels of consumption shifted in the middle of the experiment and returned to his original levels toward the end of the study. Second, 3 subjects' (JH, KC, and PZ) total consumption generally decreased as income decreased. However, total consumption for 2 of these subjects (KC and PZ) was generally constant except when income was so low that baseline levels of consumption were not mathematically possible. Subject JH, whose choice responding did not meet stability requirements after the first income manipulation (one third condition), showed gradual decreases in consumption as the experiment progressed. Finally, for Subjects JR and KS, the variability in total puffs produced by the income manipulations is similar in magnitude to the variability in total puffs across the baseline conditions. This



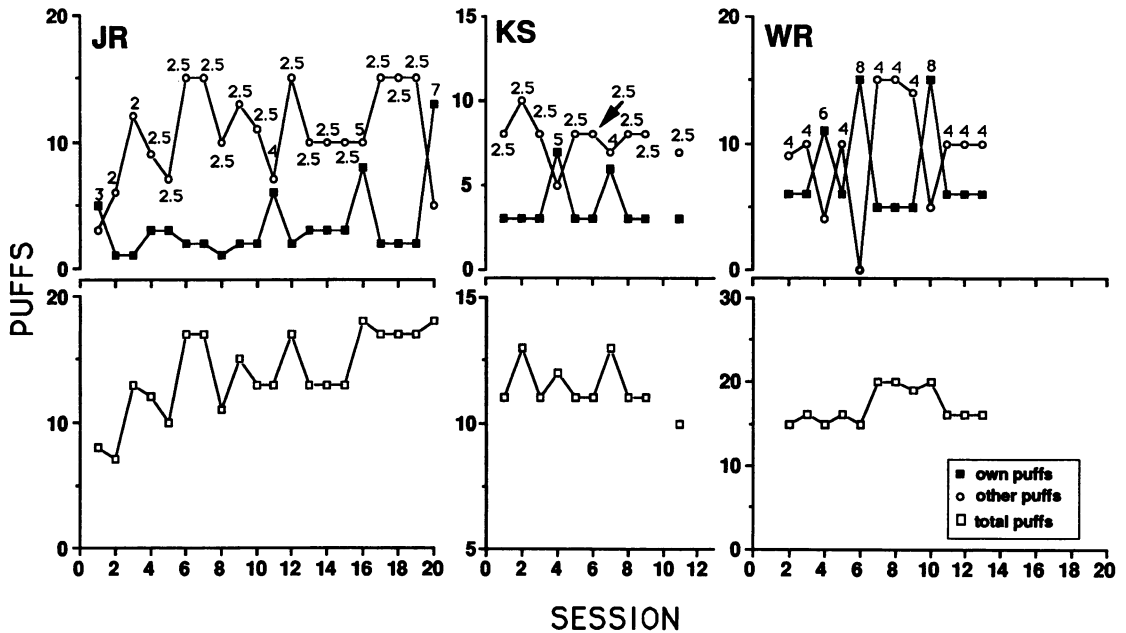


Fig. 4. Consumption (puffs) of the two reinforcers (own and other puffs) is plotted as a function of session for the 3 subjects who participated under the original procedure (top panels). The income amount for each session is indicated in dollar amounts just above one data point for each session. Also, total puffs (own + other puffs) are plotted as a function of session (lower panel). The data for sessions in which price was varied are not shown.

variability makes it difficult to interpret the effects of income on total consumption.

Another aspect of the total-consumption data is the finding that subjects sometimes did not spend their entire income even in sessions in which they responded for both types of puffs (see “\$ not spent” and “distribution within session” in Table 2). This result appeared to occur primarily because subjects conserved their income to ensure that they could obtain puffs throughout the session. As a result of this tactic, subjects frequently ran out of time in the session prior to spending their allotted income. For example, even when subjects were allotted an income that was almost (or more than) enough to respond exclusively for the more expensive puffs (i.e., own puffs), they still often purchased some or many of the cheaper brand (i.e., other puffs), even though their

overall data showed preferences for the more expensive brand (i.e., increases in own puff consumption with increases in income). This occurred especially when the first session had a \$15.00 income (see data from Subjects BT, JH, KC, and PZ). The most striking example of this pattern of responding is shown by Subject BT's data; he responded exclusively for own puffs when income was very high. This tactic is also indicated by the distribution of responding by many subjects that alternated between the more expensive puffs (own puffs) and the less expensive puffs (other puffs), especially toward the end of the session (see Table 2).

Effect of Price

Table 3 shows the effects of repeating an income condition when the price of the other

Fig. 3. Consumption (puffs) of own and other puffs is plotted as a function of session for the 4 subjects who participated under the modified procedure (top panels). The income amount for each session is indicated in dollar amounts just above one data point for each session. Also, total puffs (own + other puffs) are plotted as a function of session (lower panel). The data for sessions in which price was varied are not shown.

Table 3
Results of price manipulation.

Subject	Brand	Quantity consumed		Relative quantity consumed ^a	
		Low price	High price	Low price	High price
BT	own	20 ^b	12	54 ^b	33
	other	17 ^b	24	46 ^b	67
JH	own	12	12	37.5	60
	other	20	8	62.5	40
KC	own	14	12	58.3	60
	other	10	8	41.7	40
KS	own	3 ^b	1	37.6 ^b	10
	other	8.13 ^b	9	62.4 ^b	90
PZ	own	6	6	37.5	60
	other	10	4	62.5	40
WR	own	5.67 ^b	3	30.2 ^b	23
	other	11.44 ^b	10	69.8 ^b	77

^a Percentage of total puffs.
^b Mean, based on multiple sessions.

puffs was increased from \$0.10 to \$0.25 (except Subject KS, whose other-puffs price increased to \$0.20; Subject JR did not complete the price condition). The effect of the price increase is shown in absolute terms (consumption of own and other puffs) and in relative terms (percentage of total consumption for own and other puffs). If multiple sessions of the income condition were completed at the low price (i.e., if baseline income was used), the data for the low price represent a mean.

Increasing the price of the other puffs increased the absolute consumption of the other puffs by Subjects BT and KS and relative consumption by Subjects BT, KS, and WR. For example, BT increased consumption of the other puffs from a mean of 17 puffs to 24 puffs; WR increased relative consumption of the other puffs from 69.8% to 77%. Importantly, the absolute or relative consumption at the high price does not appear to be related simply to the absolute or relative consumption at the low price. That is, although Subjects KS and WR—who showed relative increases in consumption of the other puffs at the higher price—chose more of the other puffs at the low price, so did 2 of the 3 subjects (JH and PZ) who did not show relative or absolute increases (see Table 3).

To examine these individual differences, the acceptability of the other puffs was assessed

using postsession ratings of “how much they liked” their own puffs and the other puffs. This was done by asking subjects to respond to this question on two 100-mm visual analogue scales (VAS; 100 = “very much”) that corresponded to the two brands of puffs. These data were collected only for the 4 subjects who participated under the modified procedure. The mean “liking” scores across all sessions for the own and other puffs, respectively, were 81.2/57.5 for Subject BT (who showed an increase in consumption of the other puffs), 82.8/0.0 for Subject JH, 89.9/1.83 for Subject KC, and 87.6/0.88 for Subject PZ (all of whom showed decreased consumption of the other puffs). When liking scores for the own or other puffs are removed for those sessions in which own or other puffs were not chosen, these results do not change. That is, subjects reported very similar liking scores regardless of whether they smoked a particular brand during the session.

Finally, to examine the possibility that an increase in price may be functionally equivalent to a decrease in income, a post-hoc analysis was done that compared consumption during the high-price condition (shown in Table 2) to the consumption predicted from subjects’ income functions (shown in Figure 1). To do this, the increase in price was transformed into a decrease in income by using the observed consumption of both brands at the higher price to determine the income that would have been spent in the price condition if the other good was at its previous price of \$0.10 per two puffs. For example, BT spent \$3.00 on both brands during the price condition at an income of \$6.00. Thus, if the other puffs had cost their normal price (\$0.10 per two puffs), BT would have required an income of only \$4.20 to produce this result. Using this amount (\$4.20), if the price and income manipulation were functionally equivalent for this subject, consumption at \$6.00 income (at the high price for other puffs) should equal consumption at \$4.20 at the low price. To test this, we can plot BT’s data from the price condition at an income of \$4.20 along with the income data shown in Figure 1.

For the 3 subjects who showed relative increases in consumption for the other puffs during the price condition (BT, KS, and WR), consumption was consistent with the respective income functions for own and other puffs (see

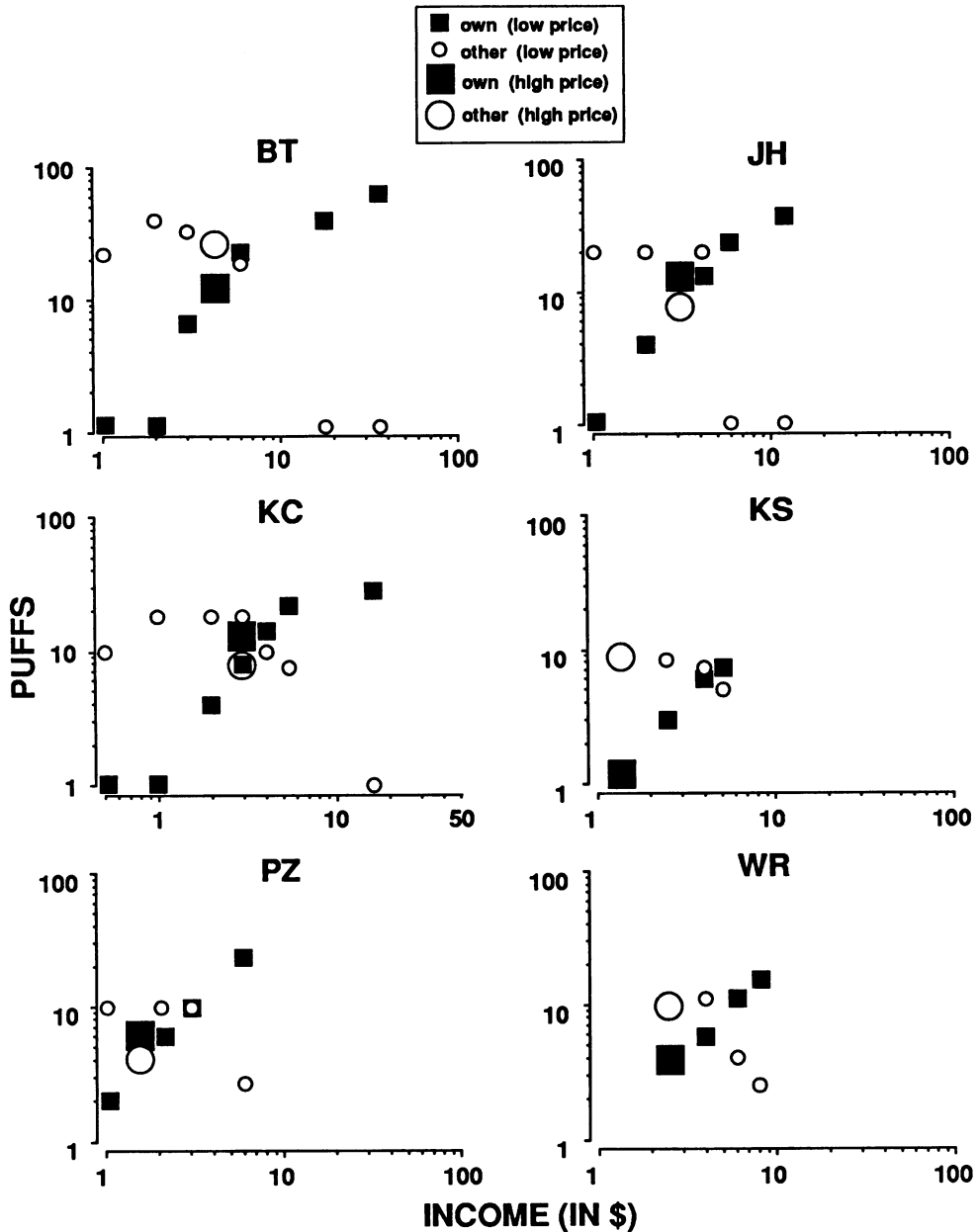


Fig. 5. The same data plotted in Figure 1 are shown for the subjects who completed the price condition (small symbols) along with the data from the price manipulation (large symbols). The latter data are plotted at the income amount that would have been spent if puffs were only \$0.10. Own-puff and other-puff data at the baseline income amounts are means across all baseline sessions.

Figure 5). However, data from the 3 subjects who showed decreases in relative consumption of the other puffs (JH, KC, and PZ) were not consistent with their respective income functions for the own and other puffs. Instead, all

3 subjects' consumption of own puffs was greater than predicted by their income function for those puffs, whereas these subjects' consumption of other puffs was clearly lower than predicted by the function for the other puffs.

DISCUSSION

The main results can be summarized as follows: First, as income increased, consumption of own puffs increased while consumption of the less expensive other puffs decreased. The magnitude of these within-subject effects was an orderly function of income. For some subjects, these effects of income on choice had little effect on total drug consumption. Second, increases in the price of the other puffs resulted in a decrease of other puff consumption in 4 subjects, but resulted in an increase in other puff consumption in the other 2 subjects who completed this condition.

As outlined in the introduction, the effects of income and price manipulations have been conceptualized in economic terms in previous studies (e.g., Silberberg *et al.*, 1987). Goods whose consumption increases as income increases are typically defined as normal goods (i.e., goods for which income and consumption are directly related), whereas goods whose consumption decreases as income increases are typically defined as inferior goods (i.e., goods for which income and consumption are inversely related). Consequently, own puffs in the present study can be defined as a normal good and other puffs as an inferior good for all 7 subjects. As shown in Figures 1 and 2, the effects of income on choice can be plotted so as to depict the nature of these goods. These functions, in which consumption is plotted as a function of income, are defined in economic terms as *Engel* curves. Moreover, the effect of increasing consumption of an inferior good by increasing its price is termed a *Giffen-good* effect. That is, when the slope of a demand (price) function is positive—as opposed to the negative slope predicted by the law of demand—the good is acting as a Giffen good (Lea *et al.*, 1987; cf. Gilley & Karels, 1991). Such an effect was shown here in 2 of 6 subjects. Note that when the slope of a demand (price) function is negative, the good is acting as an *ordinary* good. The implications of these effects and conceptualizations are discussed below.

Income Manipulations

The income manipulation employed in previous research on the effects of income on choice has been *trials per session* (Hastjarjo & Silberberg, 1992; Hastjarjo *et al.*, 1990; Silberberg *et al.*, 1987). The income manipulation in this study differed in that a medium-of-

exchange procedure was used in which subjects were provided with some income to spend throughout the session via a discrete response for one or both of two differently priced reinforcers. Despite these differences, at least four other studies have demonstrated normal and inferior goods using a concurrent-operant arrangement (Battalio *et al.*, 1991; Hastjarjo & Silberberg, 1992; Hastjarjo *et al.*, 1990; Silberberg *et al.*, 1987).

By demonstrating similar effects with a new species (humans) and a new and important class of reinforcers (drug), this study further demonstrates the utility of the income conceptualization in the study of choice. Concerning species generality, replicating the effects of income on choice with humans is of obvious importance. The present study not only shows the effects of income previously shown in animals but goes further in demonstrating more complete functional relations between income, price, and choice using a medium-of-exchange procedure common to everyday human environments. Concerning reinforcer generality, the finding that drug reinforcers are affected by income in much the same way as food reinforcers indicates that these effects of income are general and appear to be applicable to most or all primary reinforcers. Finally, the different effects of income on concurrently available reinforcers were well described by income functions (i.e., *Engel* curves) and the characterization of inferior or normal goods. This conceptualization is useful in that (a) it provides a framework to organize the differential effects of income across a range of income magnitudes that produce complete parametric functions, and (b) the two functions for normal and inferior goods provide an experimental-economic model or baseline for further complex analyses, such as the interaction between income and other more traditional factors shown to influence choice (discussed below).

The functions for normal and inferior goods provide an important demonstration that a reinforcer is not endowed with inherent properties independent of the historical and current context in which it controls behavior. For example, in the present study, income reversed preference between the two reinforcers such that reinforcer effectiveness, conventionally defined (see Katz, 1990), depended on income and not on any aspects of the reinforcers per

se (e.g., within-session rate or magnitude of reinforcement). Given that the availability of a drug is almost always constrained in drug self-administration studies, the choice observed between the concurrently available reinforcers may be due, in part, to the prevailing income. This is not to say, however, that qualitative and quantitative aspects of the reinforcer and reinforcement schedule are not important. Rather, the effect a reinforcer has on responding is determined by a confluence of these environmental variables.

This notion of intrinsic properties also applies to the behavioral-economic terms of inferior, normal, and Giffen goods. Although useful in categorizing reinforcers relative to one another across different situations, these terms describe a relationship among choice, price, and income with respect to a particular context and thus do not describe inherent properties of the reinforcer per se (cf. Hastjarjo et al., 1990). For example, although the other puffs were an inferior good for all 7 subjects in the present study, this good would likely be a normal good in a concurrent arrangement in which these puffs were available along with puffs with no nicotine content.

The effects of income on choice also have relevance to issues concerning the above liability of drugs. *Abuse liability* refers to the likelihood that any given pharmacological agent will be self-administered by humans and will be used in a nonprescribed fashion for nonmedical purposes. The drug self-administration preparation is one method for ascertaining abuse liability, based on the finding in behavioral pharmacology that drugs of abuse can serve as positive reinforcers and are self-administered by human and nonhuman animals in laboratory settings (Griffiths, Bigelow, & Henningfield, 1980; Young & Herling, 1986). The present data are relevant to this issue because they demonstrate important effects of a variable not widely shown to affect drug consumption in laboratory settings (viz. income). By showing that decreases in income in some contexts may actually increase choice of an inferior good relative to a normal good, these data suggest that laboratory analyses of abuse liability may need to examine liability in a variety of choice contexts. For example, at high income levels in the present study, the other puffs appeared to have low abuse liability relative to the subjects' own puffs; how-

ever, when income decreased, preference reversed, thus altering the assessment of abuse liability.

In terms of drug taking and drug policy, these findings suggest that decreases in the drug user's income (e.g., unemployment) may not affect drug intake (i.e., decrease it) but rather may affect drug choice (e.g., switching from cocaine to crack cocaine). This finding also suggests that the development and production of lower priced drug substitutes (e.g., crack cocaine) may increase as a result of increases in price of the already available drug, decreases in the supply of the latter, or decreases in income.

Price Manipulations

The analysis of the effects of price in the present experiment is very preliminary, yet it is an initial step toward addressing the interaction between price and income factors in determining drug consumption and the conditions under which price and income manipulations are functionally equivalent. The Giffen-good effect shown in 2 subjects has been shown in previous experimental analyses. For example, in Experiment 2 of Silberberg et al. (1987), price was manipulated by varying the probability of reinforcement for responding on the lever producing the bitter pellet. By increasing the price of the bitter pellet, choices for the bitter pellet increased, thus demonstrating a Giffen-good effect. Similar effects were also shown in rats by Hastjarjo et al. (1990) and Battalio et al. (1991).

As already stated, Giffen-good effects are paradoxical in that they are defined by positively sloping demand (price) curves, opposite in direction to those predicted by the law of demand (Allison, 1983; Lea et al., 1987). That increases in price of a reinforcer can increase its consumption is also perplexing in behavior-analytic terms, because decreases in rate of reinforcement are assumed to decrease, not increase, response rate or strength (Battalio et al., 1991; Williams, 1988). Despite these apparent paradoxes, however, the present study suggests that the Giffen-good effect is quantifiable and that an experimental analysis of such dynamic relations between price and income is possible. For example, the price manipulation was shown here to be functionally equivalent to an income manipulation for 3 subjects (2 of which showed Giffen-good ef-

fects). This conclusion is based on two findings. First, when price of the other puffs increased, Subjects BT, KS, and WR increased the proportion of money spent on other puffs (46% → 67%, 62.4% → 90%, 69.8% → 77%), whereas Subjects JH, KC, and PZ decreased the proportion spent (62.5% → 40%, 41.7% → 40%, 62.5% → 40%). Interestingly, all 3 of the latter subjects had a 60% → 40% distribution between own and other puffs at the high price (see Table 3).

Second, the data from the price condition were consistent with the income functions for the 3 subjects who showed an increase in their relative consumption of the other puffs. The other 3 subjects' outcomes, however, were inconsistent with their respective income functions. One factor that was associated with whether subjects showed functional equivalence (or the Giffen-good effect) was their self-reported acceptability of the other puffs. The 1 subject (BT) who completed the VAS scales and showed functional equivalence reported that the other good was more acceptable than the 3 remaining subjects who did not show functional equivalence or Giffen-good effects. Below is an account of why subjects' relative or absolute preferences might increase as the price of that reinforcer increases.

Economic theory suggests that Giffen-good effects are most likely to occur when a significant proportion of one's income is allocated to an essential but inferior good (Lea *et al.*, 1987). A Giffen good is observed when, as the price of the inferior good increases, the consumer compensates for the reduced purchasing power by reducing consumption of a more expensive normal good in favor of purchases of the (still cheaper) inferior good; this substitution might occur because the normal good and the inferior good share some of the same essential features. Consider, for example, Subject BT in the present study. This subject consumed about 20 puffs of both the own (\$0.50 for two puffs) and other puffs (\$0.10 for two puffs) at the \$6.00 income. Thus, he spent about \$5.00 on own puffs and \$1.00 on other puffs. Now, if the price of the other puffs is raised to \$0.25 at this income amount, one can mathematically determine choice between the two brands if he is to maintain a total of 40 puffs while simultaneously maximizing consumption of the normal good. According to this analysis, BT should decrease consumption of

own puffs to eight puffs at a cost of \$2.00 ($8/2 \times \$0.50 = \2.00) and increase consumption of other puffs to 32 puffs at a cost of \$4.00 ($32/2 \times \$0.25 = \4.00). In actuality, BT did decrease own puffs (to 12 puffs) and increased consumption of other puffs (to 24 puffs).

Although Subject BT showed a clear Giffen-good effect, the 2 other subjects (KS and WR) who showed functional equivalence between income and price did not show as robust an effect of price on choice. One interpretation of this finding is that Giffen-good effects represent one end of a continuum in which subjects respond in a manner that maintains a constant overall intake of something provided by both reinforcers (e.g., nicotine). At the other end of this continuum, subjects respond in a manner that maintains a constant intake of the normal good. According to this continuum, the 6 subjects who completed this condition could be ranked according to relative consumption of the other puffs across the low and high price as follows: KS, BT, WR, KC, JH, and PZ (see Table 3).

This discussion highlights the complexity of the interaction of price and income. Clearly, however, more laboratory research on the effects of price might help to better determine the conditions under which Giffen-good effects occur. Such research might, for example, examine whether there is a window of prices and incomes in which a Giffen-good effect would occur and whether that window is correlated with other phenomena (e.g., price at which choice between the two reinforcers is at equilibrium).

Economic Factors in the Study of Choice

The income manipulation in this and previous studies is interesting because the manipulation does not alter the rate, magnitude, or delay of reinforcement of either of the concurrently available reinforcers. This is similar to the procedure of open and closed economies, in that the variable of openness does not directly alter any quantitative or qualitative aspects of the reinforcers (Hursh & Bauman, 1987). Despite this fact, income reversed consumption in the present study such that the reinforcer that would be considered to have the greatest effectiveness depended on income and not on any aspects of the reinforcers *per se*. This finding thus suggests that the degree to which a stimulus can function as a reinforcer

cannot be completely predicted by considering only these traditional characteristics of reinforcers (e.g., rate, magnitude, delay).

Moreover, the finding that a price manipulation can have very different effects on choice across subjects (i.e., increase or decrease proportion spent on the other puffs) is another example of the need for a more complete understanding of how historical and current environmental variables interact to determine choice behavior. Importantly, the effects of income and price have been suggested by some (e.g., Battalio et al., 1991; Silberberg et al., 1987) to be incongruent with matching theory (Herrnstein, 1961, 1970; Herrnstein & Vaughan, 1980). This argument is based on the notion that increases in price decrease rate of reinforcement and thus should decrease, not increase, responding for the inferior good (i.e., decreases in rate of reinforcement, according to matching, should decrease rate of responding for that reinforcer). In contrast, however, it has been suggested that the behavioral-economic analyses examine response distribution (e.g., matching) when behavior is not at equilibrium. Although food deprivation may affect consumption between imperfect substitutes such as food and water, for example, matching theory is an account of the effects of rate of reinforcement on organisms' distribution of responding when the effects of such variables (e.g., imperfect substitutability, income) are not operating (Herrnstein & Prelec, 1992¹; Herrnstein & Vaughan, 1980). Although this latter point appears to be a valid defense of matching theory, the effects of income in this and previous behavioral-economic analyses suggest that traditional behavioral theories of choice are incomplete and should include a variable such as income in order to take into account more complex environments in which choice occurs. Variables such as income are likely to operate to some degree in most studies, even though the possibility of such influences is typically ignored.

Conclusion

Applying the income notion from economics to the study of choice has provided a method for categorizing (inferior, normal, ordinary, Giffen goods), quantifying (Engel curves), and

predicting (functional equivalence between price and income) the effects of a complex array of manipulations. Future research will need to assess the generality of these claims, especially those related to the functional equivalence between price and income. Moreover, further empirical and conceptual work will be necessary to assess the significance of these data in generating a more comprehensive theory of choice.

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¹ Herrnstein, R. J., & Prelec, R. (1992). *Giffen goods in rats: A reply to Battalio et al.* Unpublished manuscript.

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Received May 4, 1992

Final acceptance January 15, 1993